List of Figures

Chapter Seventeen

QUANTITY ESTIMATING

In addition to preparing clear and concise plans, as described in Chapter Fourteen, the designer needs to compile an accurate summary of the project quantities. This information leads directly to the project cost estimate, which combines the computed quantities of work and the estimated unit bid prices. An accurate summary of quantities is critical to prospective contractors interested in submitting a bid on the project. In addition to the INDOT *Standard Drawings* and the INDOT *Standard Specifications*, Chapter Seventeen presents additional guidelines on calculating quantities for highway, bridge and traffic projects.

17-1.0 GENERAL

17-1.01 Guidelines for Preparing Quantity Computations

When preparing quantity computations, the designer should consider the following guidelines.

1. Specifications. Cross check all items against the INDOT *Standard Specifications* and the Supplemental Specifications to ensure that the appropriate pay items, methods of measurement and basis of payment are used. If an item is not covered in the *Standard Specifications* or Supplemental Specifications, a unique special provision must be included in the contract documents to cover the item. Chapter Nineteen discusses how to prepare special provisions.

2. Pay Item Code Number. Every pay item has a unique number assigned to it for data processing. This code number is located in the computer programs CES and Estimator. Section 20-2.01 describes these programs. Only the official name and description should be used in the contract documents, special provisions and summary of quantities.

3. Rounding. The quantity of any item provided in the plans should check exactly with the figure on the computation sheets. Indicate any rounding of the raw estimated figures on the computation sheets. Unless stated otherwise, no rounding of the calculations should be done until the value is incorporated into the Quantity Summary Tables.

4. Significant Digits. When calculating quantities, carefully consider the implied correspondence between the accuracy of the data and the given number of digits.

5. Cost Estimate. Only use the total values from the Quantity Summary Tables to develop the cost estimate. Show all items described in the plans that will be included in the cost estimate on the plan sheets. The designer will be responsible for inserting these values into either CES or Estimator.

17-1.02 Computation Records

Quantity computation sheets may be generated by computer or by hand. Combine all computation sheets and bind them with a cover sheet. The preparer will sign or initial and date each sheet. The checker will also be required to sign or initial and date each sheet.

Check all values obtained through computations or use of standardized tables. For those pay items where agreements may be reached to make payment on the basis of plan quantities, an independent check should be performed and noted. Note the resolution of any differences between original and check computations. Where computations are performed by computer, an independent check is generally not required. However, check the input and review the computation output sheet for mistakes. Also, sign and date the computer output similarly to hand computation sheets.

Retain the quantity computations within the project file.

The contractor may request copies of the quantity calculations subsequent to the letting. Requests prior to the letting from contractors should be directed through the Legal Division.

17-1.03 Units of Measurement

Estimate the quantities for all contract bid items using the terms and units of measurement presented in the INDOT *Standard Specifications*. Show the values determined from the computations on the Quantity Summary Tables and elsewhere in the plans. In general, the rounding should be as follows.

1. Structural Concrete. Round structural concrete quantities to the nearest 0.1 m^3.

2. Small Quantities. For quantities where the total amount is 10 or less, round up to the next tenth of a unit (i.e., 0.1).

3. Large Quantities. For quantities greater than 10, round up the quantity to the next whole unit (i.e., 1.0).

4. Earthwork. For individual cross section areas, round to the nearest 0.1 m^2. For individual end area volumes, round to the nearest 1 m^3. For total earthwork volumes, round to the nearest 5 m^3.

5. Miscellaneous. Round pipe culverts, end bent drains, piling and bridge expansion joints up to the nearest 0.5 m.

17-1.04 Non-Defined Work

17-1.04(01) Lump-Sum Items

Only use lump sum bid items where the scope of work for the item is clearly defined, and the amount of work has a minimal chance of changing during construction. The INDOT *Standard Specifications* defines which quantities may be estimated as lump sum. Wherever practical, list the quantities for the separate items that will be included within the lump-sum item. The list should note that the separate "quantities are for estimating purposes only." Where there is a significant chance of quantity changes, the work must be bid by the unit and not lump sum.

17-1.04(02) Items Included in Other Work

In general, no item should be shown as incidental to another pay item or the contract. If any item will be included as part of another item, it must be addressed by the specifications or with a special provision. The designer should only include an item of work in another pay item where the scope of work for both is clearly defined and the probability of the quantity of either item changing is minimal. In general, minimize the use of items included in other pay items. It is impossible for bidders, or the Department, to prepare an estimate for a project which contains incidental items for which quantities or the scope of work are indeterminable.

17-1.05 Proprietary Materials

To ensure competitive bidding, the designer should restrict the use of proprietary materials on a project. Proprietary materials are defined as specifications that are so specific that only one product will satisfy the requirements, or the name of the product is actually specified. However, when a situation occurs on a project where the use of a proprietary material will enhance safety, control costs or otherwise improve the project design, the use of a proprietary material may be justifiable. Where this is applicable, the designer should consider the following.

1. Justification. The designer must prepare a justification for the use of the proprietary material. The justification should include a description of the circumstance being addressed by the proprietary material, alternative solutions considered and the reasoning why the proprietary material was chosen. Figure 17-1A, Justification for Use of Proprietary Material, illustrates the form that should be used to request approval for the proprietary material.

2. Existing Facilities. Proprietary materials may be justified where they are essential for synchronization with existing highway facilities, for which there is no equally suitable alternative.

3. Experimental. Proprietary materials may be justified for research purposes or for a distinctive type of roadway. Justifications for experimental or research items must include a work plan detailing the evaluation to be conducted. Projects on the State highway system must follow the procedures in the *INDOT Guidelines for Initiating and Reporting Experimental Features Studies*.

4. Approval. Submit the justification to the Design Division, Chief for approval. This may occur anytime between design approval and submittal of the final plans. Proprietary materials on non-exempt NHS projects will require FHWA approval. This will occur when the PS&E is submitted for the letting.

5. Approved Proprietary Materials. Lists of approved proprietary materials which have been found to be in the public interest for use may be found on the Department's website, at www.in.gov\dot\business\a_mat\index.html . Figure 17-1B lists approved proprietary materials which do not appear on the website's lists. No justification is required if such materials are specified for use on a project.

17-2.0 EARTHWORK QUANTITIES

17-2.01 Computer Computations

Earthwork computations for most projects can be determined using the computer and special design software packages. Earthwork quantities for small projects, approaches, S-lines, side roads, ditches and additional grading features may require manual calculations (see Section 17-2.02). For the computer to calculate the mainline earthwork quantities, the information typically required is as follows:

1. cross section showing existing and proposed ground surfaces;
2. shrinkage and swell factors; and
3. identification of sections not to be included (e.g., bridge sections).

The computer can generate a computation of end areas and volumes for each cross section. Show the actual computed end areas and volumes on the cross sections.

17-2.02 Manual Computations

For small projects and, to calculate special features on larger projects (e.g., approaches, ditches), it may be necessary to calculate the earthwork quantities manually. The following procedures apply.

1. Computation Sheets. See Figure 17-2A, Computation Sheet, for that used by the Department. This form can be used for documenting cross-sectional areas and volumes between cross sections.

2. End Areas. The end areas used to compute the quantities are defined by the ground lines and typical section template; see Figure 17-2B, End Area Template. After the cross sections have been plotted, determine the areas of cut and fill for each cross section using a planimeter. Include the waste of unsuitable soils, undercut, rock excavation, trench excavation and any special excavation or embankment on the section. Record the cut and fill areas for each cross section on the Computation Sheet.

3. Sum of End Areas. The SUM OF END AREAS columns are the sum of adjacent cross-section areas for the cut and fill columns. Note that the line in the figure is offset between the two end areas. This line indicates that two areas are added together.

$$V = \left(\frac{A_1 + A_2}{2} \right)(D) \qquad \text{(Equation 17-2.1)}$$

4. Length. Record the distance between stations in this column.

5. Volume Computations. Volumes for excavation (cut) and embankment (fill) are determined using the average-end-area formula,

   Where: V = volume, m^3

$A_1 + A_2$ = sum of cut or fill end areas of adjacent sections (from the SUM OF END AREAS), m^2

D = distance between sections, m

These values are recorded in the appropriate VOLUME OF CUT and VOLUME OF FILL columns on the Computation Sheet.

17-2.03 Shrinkage and Swell Factors

Fill quantities calculated manually or by the computer must be adjusted by the appropriate shrinkage factor to account for the compaction of material, loss from hauling, subsidence of the existing ground caused by the overburden, erosion and clearing operation. The factors used in the calculations will depend on the soil type, quantity to be moved and engineering judgment. Sand or gravel have smaller shrinkage factors than clay or silt. For rock excavation, it may be necessary to apply an expansion or swell factor. Figure 17-2C, Shrinkage and Swell Factors, provides factors that may be used for preliminary design purposes. A more definitive value may be available from other sources (e.g., the Geotechnical Report).

In general, only use one shrinkage factor for the entire project or for each individual balance within the project. The District may provide guidance in choosing the applicable factor(s) to be used in the calculations. The designer may need to adjust the shrinkage factor to account for smaller quantities.

17-2.04 Balancing

For most large projects, it is desirable to approximately balance the earthwork (cut and adjusted fill) for the project. Unbalanced projects will require the contractor to haul extra material (borrow) or remove the excess (excavation) from the project, which will typically increase construction costs. Balancing within the project limits can be accomplished by revising the profile grade line, revising cut and fill slopes, revising ditch profiles, etc. To determine if balancing is appropriate for a project, the designer should consider the following.

1. New Construction/Reconstruction Rural Projects. It is desirable to make a reasonable effort to balance the project.

2. 3R Rural Projects. The need for balancing the project will be determined on a project-by-project basis.

3. <u>Other Projects</u>. For urban projects, interchange projects and resurfacing projects, it is generally impractical to provide a balanced grading design. Therefore, it will not be necessary to balance earthwork on these project types.

On long projects, the designer should provide several intermediate balance points. Balance sections generally should not exceed 600 m unless an interchange, rest area or areas of deep cuts or fills are included. Usually bridges are not included within balance limits.

17-2.05 Earthwork Tabulation

To allow the contractor to determine the amount of excavation, borrow, etc., required on the project, the designer will need to include an earthwork balance table in the plans. For long roadway projects, provide a separate table for each balance section. Quantities for benching should be included in the earthwork balance. This table should be included on a road Plan and Profile Sheet, typically in the profile half of the sheet. Figure 17-2D, Earthwork Balance Table (Road Projects), illustrates the typical format that should be used. For bridge projects, one earthwork tabulation table will be required for the entire project. Show this table on the Layout Sheet. Figure 17-2E, Earthwork Tabulation (Bridge Projects) illustrates the typical format that should be used.

17-2.06 Linear Grading

The use of the linear grading pay item is generally limited to a project with a minimal amount of earthwork. Typically, this will only include the applications as follows.

1. <u>Preventative Maintenance, Functional, or Structural Pavement Treatment</u>. Linear grading consists of earth wedging at the outside edge of each shoulder where the pavement is to receive one of these treatments. If this type of earthwork is significant enough to require benching, linear grading should not be considered.

2. <u>Guardrail</u>. Linear grading consists of earth wedging behind guardrail to obtain the required earth backup for the posts. If this type of earthwork is significant enough to require benching, linear grading should not be considered.

3. <u>Median</u>. Linear grading consists of earth filling a median required for paving shoulders and placement of a concrete median barrier where travel lanes are not being added.

All other earthwork should be paid for as common excavation and borrow.

Where linear grading is being considered, the measurement for payment will be based on the length of roadway per kilometer actually constructed to the lines and grades shown in the typical cross section. Separate typical cross sections showing the limits of linear grading should be provided for the mainline, S-lines and each interchange ramp. The linear grading quantity measurement for interchange ramps should not be included in the mainline measurement. All classes of excavation (e.g., common excavation, rock excavation, unclassified excavation) are included in the linear grading pay item. If a pay item for linear grading and individual earthwork pay items are all to be included in the same contract, the linear grading limits should be shown on the plans.

The pay quantity limits should be measured along the centerline, without any deductions for bridges, etc. For example, a divided-roadway project length is from Sta. 1+000 to Sta. 9+000 "A", and includes two bridges with a combined length of 200 m. Linear grading is to be done in the median and beyond the outside shoulders. The linear grading pay length would be 8 stations.

17-2.07 B Borrow

Where B borrow is specified, it should be considered as a separate pay item. All locations where B borrow is to be placed should be shown on the plans. When estimating the quantity of B borrow, the designer should consider the following.

[Paragraph deleted.]

1. Mechanically Stabilized Earth Retaining Wall. B borrow is placed outside of the limits of structure backfill (e.g., beyond the reinforcing straps). Section 17-4.05 provides additional information for determining backfill material quantities for a retaining wall.

2. Unsuitable Materials. B borrow is used to replace unsuitable materials (e.g., peat) within the roadway structure. Section 18-2.06 provides guidance for determining the locations for the placement of B borrow with peat excavation.

3. Culvert Replacement. Where a culvert is to be removed for an existing roadway, replace the culvert excavation material with B borrow.

17-2.08 Structure Backfill

The designer should note that structure backfill will be paid for separately. When estimating the quantity of structure backfill, the designer should consider the following.

1. Drainage Structure. Section 17-2.09 discusses the procedure to estimate structure backfill quantities for a drainage structure.

[Paragraph deleted.]

2. Retaining Wall. The amount of structure backfill should be determined and shown on the cross sections at each retaining wall location. Section 17-4.05 provides additional information for retaining wall backfill.

3. Abutment. The amount of structure backfill will be determined and shown similarly to that for a concrete retaining wall (i.e., 1:1 backslope to a point 500 mm outside the neat lines of the abutment footing); see Section 17-4.05.

4. Structure Data Sheet. The estimated quantity of structure backfill is shown on the Structure Data Sheet for each structure. The total quantity is shown in the Engineer's Estimate submitted with the plans.

17-2.09 Pipe Backfill Quantity Tables

17-2.09(01) General

Section 17-2.09(06) provides pipe backfill quantity tables based on the parameters as follows:

1. pipe interior designation;
2. pipe shape;
3. backfill material; and
4. backfill method.

These tables only apply to pipe structures. Trench geometry and backfill requirements for other drainage structures (e.g., precast reinforced concrete box sections, precast reinforced concrete three- sided culverts, structural plate arch structures) have not been developed. The backfill quantities for these structure types must be determined on a case-by-case basis. The backfill quantities for structures that utilize multiple pipes must also be determined on an individual basis because these tables are only appropriate for determining the quantities of single-pipe structures.

For additional guidance on pipe backfill quantities, see the INDOT *Standard Specifications* or the INDOT *Standard Drawings,* or contact the Contracts and Construction Division's Standards Section.

17-2.09(02) Determination of Appropriate Table (Design Personnel)

Designers and construction personnel will use different procedures to select the appropriate table for calculating backfill quantities. Section 17-2.09(03) presents the procedures for construction personnel. The following summarizes the procedures for designers.

1. Pipe Material Interior Designation. The Pipe Material Sheet includes two pieces of important information. First, it indicates which pipe materials are acceptable for individual culvert and storm drain structures in the contract. Secondly, the sheet includes the interior designation (smooth or corrugated) assigned to each material. The selected pipe material designation is based on the following.

    a. Only One Material is Acceptable for the Structure. Unless the acceptable material is a fully bituminous-coated and lined steel pipe (FBC&L CSP), select a table appropriate for the required material's interior designation. If FBC&L CSP is the only acceptable material for a structure, select a corrugated interior table.

    b. Multiple Materials With the Same Interior Designation are Acceptable for the Structure. Select the table associated with the required interior designation.

    c. Multiple Materials (Some Smooth Interior, Some Corrugated Interior) are Acceptable for the Structure, and the Pipe Size Does Not Vary. If the required pipe size does not vary based on the interior designation, select a smooth interior table to calculate the required backfill quantity for the structure. The only exception is FBC&L CSP. If FBC&L CSP is the only acceptable material with a smooth interior designation, then select a corrugated interior table to calculate the backfill quantity for the structure.

    d. Multiple Materials (Some Smooth Interior, Some Corrugated Interior) are Acceptable for the Structure, and the Pipe Size Varies. If the required pipe size varies based on the interior designation, include in the plans the required backfill quantity for both structure alternatives. Use a smooth interior table to determine the required backfill for the smooth interior alternative and a corrugated interior table to determine the backfill required for the corrugated structure alternative. The only exception to the above rule is FBC&L CSP. If FBC&L CSP is the only acceptable smooth interior material, use a corrugated interior table to determine the backfill quantity for both the smooth and corrugated structure alternatives. However, the backfill quantities associated with the smooth interior structure alternative must be used to determine the overall quantities for backfill items included in the schedule of quantities for the contract.

2. Pipe Shape. The pipe shape will either be circular or deformed. Select a backfill table appropriate for the pipe shape.

3. Backfill Material. Unless instructed otherwise, structure backfill is required for all culvert and storm drain structures, except field entrance culverts which are backfilled with suitable excavated material. Therefore, the designer should select a structure backfill table to determine the required backfill quantities. If the designer is instructed to utilize flowable backfill, a flowable backfill table should be used to determine the quantity of the required flowable backfill encasement and the quantity of structure backfill required to fill the remainder of the trench.

4. Backfill Method. Review the INDOT *Standard Drawings* to determine the appropriate backfill method for the structure Method 1 or Method 2. Select a backfill table based on the proper backfill method to determine the required backfill quantities.

17-2.09(03) Determination of Appropriate Table (Field Personnel)

Field personnel will generally know which pipe material is installed at a structure site. The table required for backfill quantity calculations for the final construction record is based on the interior designation of the pipe material actually installed. However, there are the following exceptions.

1. If FBC&L CSP is installed at a structure site, use a corrugated interior table to calculate backfill quantities.

2. If the plans indicate that a structure requires different smooth interior and corrugated interior pipe sizes, calculate the final construction record backfill quantities based on the proposed smooth interior structure alternative, regardless of the pipe material and size actually installed.

17-2.09(04) Instructions for Using Tables

If the list of acceptable pipe materials for a structure includes materials with different corrugation profiles, the structure backfill quantity will be based on the largest corrugation profile shown on the list.

1. Method 1. Method 1 backfill tables are slightly more complicated than Method 2. In addition, the steps associated with flowable backfill tables differ somewhat from those required for the structure backfill tables. These are discussed below.

   a. Flowable Backfill Tables. Where flowable backfill is used, it is only required to the V_c dimension above the pipe. The remainder of the trench, if any, is backfilled with structure backfill. Therefore, the backfill portion of the table consists of two columns. The left backfill column contains the area of the trench that requires flowable backfill. The quantity of flowable backfill can be directly calculated by multiplying the tabulated area for the required pipe size by the length of the pipe subjected to Method 1 backfill. The quantity for structure backfill depends on the remaining trench depth. At the bottom of the table is an equation that should be used to calculate the remaining trench area. This equation requires two sets of input data. The first is the remaining trench depth (expressed as T_c-V_c or total cover minus the flowable backfill cover) and the second is a constant, designated as K. The right column in the backfill portion of the table tabulates the K constant for each standard pipe size. Use these input data in the tabulated equation to determine the backfill area for structure backfill. The required structure quantity of structure backfill is determined by multiplying the calculated area by the length of the pipe subjected to Method 1 backfill.

   b. Structure Backfill Tables. The backfill portion of these tables consists of two columns. The left column contains the backfill area to the top of the pipe. The remaining backfill area is calculated using an equation located at the bottom of the table. Similar to the Flowable Backfill tables, the equation requires two input data items, the remaining trench depth (T_c) and the constant K. The K constant is tabulated in the right column of the backfill portion of the table. The remaining trench area obtained from the tabulated equation is then added to the backfill area below the pipe crown to determine the total backfill area. The total backfill quantity is determined by multiplying the total trench area by the length of pipe subjected to Method 1 backfill.

   Section 17-2.09(05) provides sample backfill quantity calculations which provide additional guidance to determining Method 1 backfill quantities.

2. Method 2. Where Method 2 backfill tables are required, use the following steps.

a. Step 1. Once the correct table is determined, use the left column to locate the required pipe size.

b. Step 2. Follow the row associated with the required pipe size and locate the tabulated area entry in the Backfill column to the right.

c. Step 3. Multiply the tabulated area by the length of the pipe subjected to method 2 backfill to calculate the required backfill quantity.

Section 17-2.09(05) provides sample backfill quantity calculations which provide additional guidance to determining Method 2 backfill quantities.

17-2.09(05) Sample Backfill Quantity Calculations

Example 17-2.1

Given: 900-mm Type 1 Pipe
Smooth and corrugated interior materials are acceptable
Method 1 Backfill
Structure Backfill
Backfill Length = 15.0 m
Total Cover = 1.2 m

Problem: Determine the quantity of backfill required.

Solution: Use the following steps.

Step 1: Determine Appropriate Backfill Table. For designers, use a smooth interior table when the list of acceptable materials includes both smooth and corrugated interior materials and required pipe size does not vary depending on the interior designation. Therefore, for this example, use Figure 17-2H, Method 1 – Structure Backfill Quantities (Circular Smooth Interior Pipe), to determine the backfill quantity. Field personnel will select the appropriate table based on the actual pipe material installed. For example, if the contractor installed a pipe with a corrugated interior designation, field personnel will use Figure 17-2F, Method 1 – Structure Backfill Quantities (Circular Corrugated Interior Pipe). For this example, assume that a smooth interior pipe material was installed and that Figure 17-2H is the correct table.

Step 2: Determine Backfill Area to Pipe Crown. From Figure 17-2H, the area is 1.16 m^2.

Step 3: Determine Backfill Area Above Pipe. Using the equation at the bottom of the table, the amount of cover (1.2 m) and the tabulated K (4.02), the backfill area above the pipe is 2.53 m^2.

Step 4: Determine Structure Backfill Quantity. Add the backfill areas (1.16 m^2 + 2.53 m^2 = 3.69 m^2) and multiply it by the length of pipe subject to Method 1 backfill (15.0 m). The resulting structure quantity is 38.0 m^3.

Example 17-2.2

Given: 375-mm Type 3 Pipe
Smooth and corrugated interior materials are acceptable
Method 2 Backfill
Structure Backfill
Backfill Length = 9.5 m

Problem: Determine the quantity of backfill required.

Solution: Use the following steps.

Step 1: Determine Appropriate Backfill Table. For designers, use Figure 17-2V, Method 2 – Structure Backfill Quantities (Circular Smooth Interior Pipe). Smooth interior tables must be used when the list of acceptable materials includes both smooth and corrugated interior materials and the required pipe size does not vary depending on the interior designation. For field personnel, select the appropriate table based on the interior designation for the pipe material actually installed. For this example, assume that a material with a smooth interior has been installed.

Step 2: Determine Backfill Area. From Figure 17-2V, the area is 0.16 m^2.

Step 3: Determine Structure Backfill Quantity. Multiply the area from Step 2 by the length of pipe subject to Method 2 backfill (9.5 m). The resulting structure quantity is 1.5 m^3.

Example 17-2.3

Given: 600-mm Type 2 Pipe
Method 1 Backfill
Flowable Backfill
Backfill Length = 105.5 m
Cover = 3.0 m

Problem: Determine the quantity of backfill required.

Solution: Use the following steps.

Step 1: Determine Appropriate Backfill Table. Figure 17-2 O, Method 1 – Flowable Backfill Quantities (Circular Smooth Interior Pipe) is the correct table for both designers and field personnel because all Type 2 pipe materials have a smooth interior designation.

Step 2: Determine Flowable Backfill Area. From Figure 17-2 O, the area is 1.27 m^2.

Step 3: Determine Flowable Backfill Quantity. Multiply the area for Step 2 by the length of pipe subjected to Method 1 backfill (105.5 m). The quantity is 134.0 m^3.

Step 4: Determine Structure Backfill Area. Using the equation at the bottom of the table, the remaining trench depth (3.0 m - 0.5 m = 2.5 m) and the tabulated K (2.95), the structure backfill area is 4.21 m^2.

Step 5: Determine Structure Backfill Quantity. Multiply the area from Step 4 by the length of pipe subject to Method 1 backfill (105.5 m). The resulting structure quantity is 444.0 m^3.

Example 17-2.4

Given: 900-mm Smooth or 1050-mm Corrugated (68 mm x 13 mm and 75 mm x 25 mm Corrugation Profiles) Type 1 Pipe
Method 1 Backfill
Structure Backfill
Backfill Length = 20.0 m
Smooth Interior Cover = 0.85 m

Corrugated Interior Cover = 0.70 m

Problem: Determine the quantity of backfill required.

Solution: Use the following steps.

Step 1: Determine Appropriate Backfill Table(s). For designers, use Figure 17-2H, Method 1 – Structure Backfill Quantities (Circular Smooth Interior Pipe), to determine the backfill quantity for the smooth alternative and Figure 17-2F, Method 1 – Structure Backfill Quantities (Circular Corrugated Interior Pipe), for the corrugated structure alternative. Field personnel will only refer to Figure 17-2H when calculating the backfill quantities for the final construction record.

Step 2: Determine Backfill Area to Pipe Crown for Smooth Alternative. From Figure 17-2H, the area is 1.16 m^2.

Step 3: Determine Backfill Area Above Pipe for Smooth Alternative. Using the equation at the bottom of the table, the cover (0.85 m) and the tabulated K (4.02), the backfill area above the pipe is 1.77 m^2.

Step 4: Determine Structure Backfill Quantity for Smooth Alternative. After adding the backfill areas (1.16 m^2 + 1.77 m^2 = 2.93 m^2), multiply this value by the length of pipe subject to Method 1 backfill (20.0 m). The resulting structure quantity for the smooth alternative is 58.6 m^3.

Step 5: Determine Backfill Area to Pipe Crown for Corrugated Alternative (Designer Only). From Figure 17-2F, the area is 1.09 m^2. Use the value tabulated for the 75-mm x 25-mm corrugation profile because it is the largest among the list of acceptable materials.

Step 6: Determine Backfill Area Above Pipe for Corrugated Alternative (Designer Only). Using the equation at the bottom of the table, the cover (0.70 m) and the tabulated K (3.89), the backfill area above the pipe is 1.40 m^2.

Step 7: Determine Structure Backfill Quantity for Corrugated Alternative (Designer Only). After adding the backfill areas (1.09 m^2 + 1.40 m^2 = 2.49 m^2), multiply this value by the length of pipe subject to Method 1 backfill (20.0 m). The resulting structure quantity for the smooth alternative is 49.8 m^3.

Example 17-2.5

Given: 900-mm Smooth or 1050-mm Corrugated (68 mm x 13 mm and 75 mm x 25 mm Corrugation Profiles) Type 1 Pipe
Method 1 Backfill
Flowable Backfill
Backfill Length = 20.0 m
Smooth Interior Cover = 0.85 m
Corrugated Interior Cover = 0.70 m

Problem: Determine the quantity of backfill required.

Solution: Use the following steps.

Step 1: Determine Appropriate Backfill Table(s). This example is identical to Example 17-2.4, except that flowable mortar backfill is required. Designers should use Figure 17-2 O, Method 1 – Flowable Backfill Quantities (Circular Smooth Interior Pipe), to determine the backfill quantities for the smooth alternative and Figure 17-2M, Method 1 – Flowable Backfill Quantities (Circular Corrugated Pipe), to determine the quantities for the corrugated structure alternative. Field personnel should only use Figure 17-2 O.

Step 2: Determine Flowable Backfill Area for Smooth Alternative. From Figure 17-2 O, the area is 2.05 m^2.

Step 3: Determine Flowable Backfill Quantity for Smooth Alternative. Multiply the area from Step 2 by the length of pipe subject to Method 1 backfill (20.0 m). The flowable backfill quantity for the smooth alternative is 41.0 m^3.

Step 4: Determine Structure Backfill Area for Smooth Alternative. Using the equation at the bottom of the table, the remaining trench depth (0.85 m - 0.50 m = 0.35 m) and the tabulated K (4.02), the backfill area above the pipe is 0.71 m^2.

Step 5: Determine Structure Backfill Quantity for Smooth Alternative. Multiply the backfill area from Step 4 by the length of pipe subject to Method 1 backfill (20.0 m). The resulting Structure Backfill quantity for the smooth alternative is 14.3 m^3.

Step 6: Determine Flowable Backfill Area for Corrugated Alternative (Designer Only). From Figure 17-2M, the area is 1.98 m^2. Use the value tabulated for the 75-mm x 25-mm corrugation profile because it is the largest among the list of acceptable materials.

Step 7: Determine Flowable Backfill Quantity for Corrugated Alternative (Designer Only). Multiply the area from Step 6 by the length of pipe subject to Method 1 backfill (20.0 m). The flowable backfill quantity for the smooth alternative is 39.6 m^3.

Step 8: Determine Structure Backfill Area for Corrugated Alternative (Designer Only). Using the equation at the bottom of the table, and the remaining trench depth (0.70 m - 0.50 m = 0.20 m) and the tabulated K (3.93), the structure backfill area is 0.40 m^2.

Step 9: Determine Structure Backfill Quantity for Corrugated Alternative (Designer Only). Multiple the backfill area from Step 8 by the length of pipe subject to Method 1 backfill (20.0 m). The resulting structure quantity for the smooth alternative is 7.9 m^3.

* * * * * * * * * *

17-2.09(06) Backfill Tables

Section 17-2.09(01) lists the various parameters used to develop the backfill tables. The tables have been segregated as follows.

1. Method 1 Structure Backfill Tables. The following figures apply to structure backfill using Method 1.

    a. Figure 17-2F – Circular Corrugated Interior Pipe
    b. Figure 17-2G – Circular Structural Plate Metal Pipe
    c. Figure 17-2H – Circular Smooth Interior Pipe
    d. Figure 17-2 I – Deformed Corrugated Interior Pipe
    e. Figure 17-2J – Deformed Corrugated Interior (Structural Plate Aluminum Alloy) Pipe
    f. Figure 17-2K – Deformed Corrugated (Structural Plate Steel) Pipe
    g. Figure 17-2L – Deformed Smooth Interior Pipe

2. Method 1 Flowable Backfill Tables. The following figures apply to flowable backfill using Method 1.

    a. Figure 17-2M – Circular Corrugated Pipe
    b. Figure 17-2N – Circular Corrugated (Structure Plate) Pipe
    c. Figure 17-2 O – Circular Smooth Interior Pipe

d. Figure 17-2P – Deformed Corrugated Interior Pipe
e. Figure 17-2Q – Deformed Corrugated (Structural Plate Aluminum Alloy) Pipe
f. Figure 17-2R – Deformed Corrugated (Structural Plate Steel) Pipe
g. Figure 17-2S – Deformed Smooth Pipe

3. Method 2 Structure Backfill Tables. The following figures apply to structure backfill using Method 2.

   a. Figure 17-2T – Circular Corrugated Interior Pipe
   b. Figure 17-2U – Circular Structural Plate Metal Pipe
   c. Figure 17-2V – Circular Smooth Interior Pipe
   d. Figure 17-2W – Deformed Corrugated Interior Pipe
   e. Figure 17-2X – Deformed Corrugated Interior (Structural Plate Aluminum Alloy) Pipe
   f. Figure 17-2Y – Deformed Corrugated (Structural Plate Steel) Pipe
   g. Figure 17-2Z – Deformed Smooth Interior Pipe

4. Method 2 Flowable Backfill Tables. The following figures apply to flowable backfill using Method 2.

   a. Figure 17-2AA – Circular Corrugated Pipe
   b. Figure 17-2BB – Circular Corrugated (Structural Plate) Pipe
   c. Figure 17-2CC – Circular Smooth Interior Pipe
   d. Figure 17-2DD – Deformed Corrugated Interior Pipe
   e. Figure 17-2EE – Deformed Corrugated (Structural Plate Aluminum Alloy) Pipe
   f. Figure 17-2FF – Deformed Corrugated (Structural Plate Steel) Pipe
   g. Figure 17-2GG – Deformed Smooth Pipe

17-3.0 ROADWAY QUANTITIES

17-3.01 Pavement Materials

Chapter Fifty-two discusses INDOT pavement design criteria. It also provides information for quantity determinations for subgrades, asphalt materials, concrete materials, underdrains and geotextile wraps. Figure 17-3A, Roadway Factors, provides factors that can be used to determine asphalt pavement and other roadway quantities.

17-3.02 Subgrade Treatment

The subgrade is defined as the top surface of a roadbed upon which the pavement structure and shoulders are constructed. The subgrade area should be computed for at-grade, cut, and cut-to-fill transitions only. The width of the treatment is between points which are 0.3 m outside the edges of paved shoulders or back faces of curbs. The lateral limits and type of subgrade treatment should be shown on the Typical Cross Sections in the plans.

All isolated subgrade treatment areas within the project limits, including those on S-lines of high type and substantial length, should be summed to obtain the total subgrade treatment area for the entire project. A divided highway may have parallel but separate subgrade treatment areas depending upon the width of the median.

Typically, a roadway project will contain several cut and fill areas within the project limits. Fill areas above the natural ground line should not be included in the computation.

The type of subgrade treatment to be used will be specified in the geotechnical report as subgrade treatment type A, B, C, D, or E. If the geotechnical report does not specify the subgrade treatment type, the designer should send a memorandum requesting the subgrade treatment to the Materials and Tests Division's Geotechnical Section. The preliminary field check plans transmitted with the memorandum should include projected AADT figures and subgrade areas tabulated as shown in the following example.

Line	Projected AADT	Treatment Area, m^2
"A"	20,000	9,000
"S-1-A"	450	300
"S-2-A"	850	400

The subgrade treatment methods are as follows.

1. Type A. This treatment consists of 400 mm of chemical soil modification, or 300 mm of the subgrade excavated and replaced with coarse aggregate No. 53. Where granular soils classified in accordance with AASHTO M 145 as A-1, A-2, or A-3 exist, the subgrade may be treated by compacting 600 mm to density and moisture requirements.

2. Type B. This treatment consists of 200 mm of chemical soil modification, or 150 mm of the subgrade excavated and replaced with coarse aggregate No. 53. Where granular soils classified in accordance with AASHTO M 145 as A-1, A-2, or A-3 exist, the subgrade may be treated by compacting 300 mm to density and moisture requirements.

3. Type C. This treatment consists of 600 mm compacted to the density and moisture requirements, or 300 mm (12 in.) of subgrade excavated and replaced with coarse aggregate No. 53, or 400 mm of chemical soil modification.

4. Type D. This treatment consists of 300 mm compacted to the density and moisture requirements, or 150 mm of subgrade excavated and replaced with coarse aggregate No. 53, or 200 mm of chemical soil modification.

5. Type E. This treatment consists of 150 mm compacted to the density and moisture requirements, or 150 mm of subgrade excavated and replaced with coarse aggregate No. 53.

For each of the subgrade treatment types described above, for at-grade, cut, and cut-to-fill transitions, the contractor is to choose from the applicable options for each type. The designer should not consider these options when determining subgrade treatment quantities, and should not show specific options on the plans.

The pavement design recommendations will indicate where subgrade treatment is to be used. It is generally not applicable to intersections and widening where the process is not practical. The typical sections should indicate where subgrade treatment is required.

17-3.03 Placing Pipes Under Existing Pavements

If the placing of a new pipe is required under an existing roadway, the detail shown in Figure 17-3C should be shown on the plans. This figure does not apply where jacking or boring is used. In addition, the designer should consider the following.

1. Removal. Removal of asphalt pavement should be paid for as "Common Excavation" and for concrete pavements "Removal of Pavement."

2. Patching. Where the length of pavement removal is 30 m or less, use the pay item "HMA for Patching," "Portland Cement Concrete for Patching *(Pavement Type)*" or "Patching, *(Full) (Partial)* Depth, *(type)* Concrete Pavement." For lengths greater than 30 m, use the standard roadway pay items.

17-3.04 Subbase and Underdrains for Cement Concrete Pavements

17-3.04(01) Subbase

The subbase under cement concrete pavements consists of two aggregates˜ Coarse Aggregate Size No. 8 on top of Compacted Aggregate Base, Type O, No. 53. The *INDOT Standard Specifications* provides the criteria for thickness of these aggregates. The bottom layer of this composite subbase should be designated on the plans as a separation layer. Include this separation layer on all cement concrete mainlines, S-lines and all approach pavements except driveways. For estimating and payment purposes, combine the quantities for both aggregate types and designate them together as Subbase for Cement Concrete Pavements. For additional guidance, see Chapter Fifty-two and the INDOT *Standard Specifications*.

17-3.04(02) Underdrains

Underdrains are required under all new pavements. Locate the underdrain in pavement structure as shown in Chapter Fifty-two and provide a detail in the construction plans. For additional guidance on underdrains, see Chapter Fifty-two and the INDOT *Standard Specifications*. Where underdrains are used, include the following pay items.

1. Underdrain. The underdrain will consist of the pay items as follows:

    a. Pipe, Type 4, Circular, *(size)* mm;

    b. Geotextile for Underdrains; and

    c. Aggregate for Underdrains. Note that only the aggregate placed below the subgrade will be paid for as aggregate for underdrains.

2. Underdrain Outlets. Underdrain outlets will consist of the pay items as follows:

    a. Pipe Underdrain Outlet, *(size)* mm;
    b. Outlet Protector, *(type)* ; and
    c. Delineator Post.

17-3.05 Non-Standard Concrete Median Barriers

Non-standard concrete median barriers may be required on horizontal curves, superelevation transitions and other locations where the barrier height varies from the standard dimensions, or where the median barrier is attached to a concrete footing or wall cap. Identify these locations on the plans and include the pay items Concrete, Class A and Reinforcing Steel, on the plans. Also, include a special provision in the contract.

Short lengths of irregular concrete median barrier sections used in conjunction with the standard shape, barriers at approaches to bridge piers, sign foundations and other similar supports should be considered concrete median barrier and paid for per meter of concrete barrier.

17-3.06 Curb Ramps (Concrete)

Figure 17-3D, Curb Ramp Areas, provides typical quantity amounts that should be used for the various INDOT curb ramps. Section 51-1.0 provides additional criteria on where each curb ramp should be used. Note that the corner radii only makes a small difference in the size of the curb ramp. Therefore, for all corner radii, use the values presented in Figure 17-3D. However, if other conditions change (e.g., sidewalk widths, median widths), the areas in Figure 17-3D should be recalculated. Curb ramps are paid for by the square meter.

17-3.07 Sodded, Paved and Riprap Ditches

As a general guide, longitudinal ditch slopes less than 1% will be seeded, slopes which are 1% to 2.99% will usually require sodding and slopes 3% or greater will require a paved side ditch or riprap lining. However, in areas of poor soil, slopes less than 3% may be paved or lined with riprap. Riprap ditches are typically used in rural areas and should be avoided in urban areas. The final ditch protection type will be determined at the field check in consultation with the district. The following sections discuss how to estimate the quantities for these ditch types.

17-3.07(01) Sodded Ditches

Standard sodded ditches are ditches that are parallel to the pavement profile grade line. Special sodded ditches are ditches that vary in elevation with respect to the pavement profile grade line. Depending on the side slopes, either ditch type may be used within the clear zone. Do not use ditches with side slopes of 3:1 or steeper within the clear zone.

In general, all sodded ditches should be sodded to a point 300 mm above the flow line. Figure 17-3E, Sodded Ditch Quantities, provides the factors that can be used to determine the sodding quantities for a 1.2-m wide sodded ditch based on various side slopes.

17-3.07(02) Paved Side Ditches

The INDOT *Standard Drawings* and Figure 17-3F, Paved Side Ditches, illustrate the various paved side ditches used by the Department. To determine the type of paved side ditch, use the criteria provided in Section 30-3.03(02).

When computing quantities, the designer should consider the following.

1. Limits. Where a paved side ditch meets a sodded or unsodded ditch flowing in the same direction, extend the limits of the paved side ditch 8.0 m beyond the theoretical point of termination. Greater distances may be required under special circumstances.

2. Measurements. Paved side ditches are measured from station to station and paid for by the type and length of side ditches in meters. For grades 20% or less, increase the measured distance from the plans by 5% to compensate for grades. For grades greater than 20%, increase the measured distance by 10%.

3. Transitions. Paved side ditch transitions are required at intersections with earth ditches and pipe culverts. Convert these transitions to equivalent lengths of the type of paved side ditch specified. Transitions of 3 m or less are also required between two different types of paved side ditches. These transitions are provided for in the pay length of the larger type of paved side ditch type specified.

4. Cut-Off Walls. Cut-off walls are required at the beginning and end of all paved side ditches. Each cut-off wall is considered to be equivalent to 2.5 m of the paved side ditch specified at the location (i.e., add an additional 2.5 m to the measured paved side ditch quantity for each cut-off wall).

5. Lugs. Lugs are provided to prevent sliding on steep slopes. Each lug is considered equivalent to 2.5 m of paved side ditch specified at the location (i.e., add an additional 2.5 m to the measured paved side ditch quantity for each lug provided). Lugs should be provided at the locations as follows:

    a. 3 m downslope from a grade change;

    b. 3 m downslope from the intersection of different types of paved side ditches;

    c. at the downslope end of a transition between different types of paved side ditches; and

d. at the intervals shown in Figure 17-3G, Lug Intervals.

6. Sodding. Provide sodding next to the paved side ditch as shown in Figure 17-3F, Paved Side Ditches. To determine the sodding quantities next to paved ditches, use a factor of 0.8 m^2 per meter of paved side ditch. This factor is applicable for all paved ditch types.

17-3.07(03) Riprap Lined Ditches

When designing riprap lined ditches, consider the following:

1. With slopes of 3% to 10%, revetment riprap can be used. For slopes steeper than 10%, the designer will need to design the riprap size and use Class I or Class II riprap.

2. At the bridge cone, use riprap specified for the bridge cone.

3. Where a riprap ditch meets a sodded or unsodded ditch flowing the same direction, extend the limits of the riprap 8.0 m beyond the theoretical point of termination.

4. Place geotextile under the riprap.

5. Show the ditch details on the plans.

6. Within the clear zone, only use uniform riprap.

17-3.08 Mailbox Assemblies and Mailbox Approaches

Most non-Interstate-route, rural projects will require mailbox assembly quantities. Section 51-11.0 provides guidance on the design and location of mailbox approaches. If no mailbox locations are shown on the topographic survey, the designer should not assume there are no mailboxes present on the route. In the absence of survey information, the designer should check for mailboxes at the field check review. The use of the photo-log will also aid in determining the location and number of mailboxes.

Figure 17-3H, Mailbox Summary Table, illustrates the mailbox quantities that should be used. In those cases where the designer is certain that there are no mailboxes located within the project limits, there is no need to include these pay items in the plans.

17-3.09 Monuments

17-3.09(01) General

Monuments are set to define certain civil boundaries (e.g., section lines) and to permanently establish vital survey points. Monuments used by the Department are shown in the INDOT *Standard Drawings* and are defined as follows.

1. Monument Type A. Use this monument type with vitrified brick or asphalt surface on concrete base.

2. Monument Type B. Use this monument type with flexible pavements.

3. Monument Type C. This monument is used where a monument is required outside the pavement area.

4. Monument Type D. Use this monument type with concrete pavements.

5. Bench Mark Post. Used to establish Department bench marks.

6. Section Corner Monument. Used to monument section corners.

It is the responsibility of the designer to select the type of monument that best suits the location where a monument is required.

17-3.09(02) Civil Boundaries

The following will apply to monuments at civil boundaries.

1. Location. Provide monuments at all section corners and quarter section corners that fall within the right-of-way for a new facility or for a facility to be reconstructed except as noted in Item 2 below. Where a section line crosses a limited access facility, provide a monument at the intersection of the right-of-way line and the section line. For fenced, limited access right-of-way, place the monument outside the fence at each point where the section line crosses the limited access right-of-way line.

2. Responsibilities. The District will request the local county surveyor to establish all section corners and section lines not already defined by monuments at the time of construction. Should the county surveyor fail to establish such points as requested, the District will eliminate any monuments provided for this purpose from the construction contract.

3. Plans. Designate all monuments by type and show them on the plans with an arrow to their approximate location.

17-3.09(03) Survey Points

Survey line points and their respective monuments are used as the basis for the description of all right-of-way that is acquired for a project. With respect to right-of-way description, they are as significant as section corners. Survey line monuments must be set by a registered land surveyor. Resurface projects or projects not requiring new right-of-way are exempt from these requirements. Other projects not requiring new right-of-way may also be exempt. The following will apply to providing survey monuments.

1. Monumenting PIs, PCs and PTs. The following will apply.

    a. Where the PI falls within the right-of-way, provide a monument at the PI.

    b. Provide a monument at all PCs and PTs.

    c. Designate all monuments by type and show them on the plans with an arrow to their approximate location.

2. Monumenting Beginning and End of Projects. Place a monument on the survey centerline at the beginning and the end of every project.

3. Monumenting POTs and POCs. The following will apply.

    a. It is not necessary to monument all POTs and POCs. These intermediate points will be monumented as necessary so that the maximum interval between adjacent monuments does not exceed 300 m.

    b. The designer must inspect the plans and select intermediate points to be monumented so that an instrument man can see a tripod with a target set on an adjacent monument in at least one direction. For this purpose, use a line-of-sight 1.2 m above adjacent monuments.

c. Locate monuments so that the line-of-sight between adjacent monuments will fall within the right-of-way.

d. Where practical, the monuments required to define POCs and POTs should coincide with a POC or a POT established during the original survey for greater accuracy in locating the monument.

e. Designate POC or POT monuments by type and station and show them on the plans with an arrow to their approximate location.

17-3.09(04) INDOT Bench Marks

All highway projects, both new construction and reconstruction projects, should provide a bench mark at least every 2.5 km. These bench marks should be located as follows.

1. Structures. Include bench marks on all bridges, slab top culverts and box culverts. Where twin structures or dual structures are constructed at the same location, a bench mark is only required on one structure.

2. Non-Structures. Where the spacing of structures is in excess of 2.5 km, show bench mark posts on the plans and space them so that the maximum spacing between bench marks is 2.5 km.

3. Plans. Designate bench mark posts required under Item 2 by station on the plans with the following note:

   "Bench Mark Post Required
   Station _______ + _______"

17-3.09(05) Correcting Plans

The District Construction Engineer will notify the Survey Unit Supervisor in the Design Division whenever monuments are eliminated from the contract or the location of a monument is changed. The "as-built plans" are to reflect any changes made to the monument locations shown in the construction plans.

17-3.09(06) R/W Markers

For information on right-of-way markers, see Section 85-7.0.

17-3.09(07) National Geodetic Survey Bench Marks

All National Geodetic Survey (NGS) bench marks disturbed by highway construction must be re-established. It is the responsibility of the Contractor to secure the replacement disk for these bench marks. In addition, the construction plans should include the following note.

> "N.G.S. Bench Mark Post No. __________, __________ Rt. (or Lt.) of Station __________ to be re-established by the Contractor."

Information for field procedures on resetting NGS bench marks may be obtained by making the contacts as follows:

For Illinois bench marks:

Illinois Geodetic Advisor
IDOT Administration Building, Room 005
2300 South Dirksen Parkway
Springfield, IL 62764
(217) 524-4890

For Indiana bench marks:

Coordinator for Indiana
Area of Surveying Engineering
School of Civil Engineering
Purdue University
1284 Civil Engineering Building
West Lafayette, IN 47907-1284
(765) 494-2165

17-3.09(08) National Geodetic Survey (NGS) Horizontal Control Points (formerly Triangulation Points)

The section manager or designer is responsible for notifying the National Geodetic Survey whenever NGS horizontal control points must be re-established because of proposed highway construction. This notification will be by letter from the Design Division Chief and should be made at the time the plans are sent to the district.

It is not necessary to include monuments in the construction plans for use in re-establishing NGS horizontal control points; however, the appropriate monuments should be requested from the NGS to replace the existing horizontal control point monuments being re-established. The NGS address is as follows:

National Geodetic Survey
NOAA RC
325 Broadway
Boulder, CO 80303

17-3.09(09) United States Geological Survey Bench Marks

All United States Geological Survey (USGS) bench marks disturbed by highway construction must also be re-established. Information on resetting USGS bench marks may be obtained by contacting the following:

U.S. Geological Survey
Mid-Continent Mapping Center, MS 309
1400 Independence Road
Rolla, MO 65401
Telephone: (573) 308-3808
Fax: (573) 308-3652

17-3.10 Seeding and Sodding

17-3.10(01) Seeding for Grading and Paving Projects

The following will apply.

1. Rural Areas 4000 m^2 or Larger. Rural areas within the right-of-way that are not sodded or paved should be seeded as follows.

    a. Seeding. Use the seed mixture R as specified in the INDOT *Standard Specifications*. Estimate the quantity assuming an application rate of 190 kg/ha.

    b. Mulching. Use the pay item Mulching Material and estimate it at a rate of 4.5 Mg/ha.

c. Fertilizer. For estimating purposes, assume an application rate of 900 kg/ha.

2. Urban Areas 4000 m^2 or Larger. Urban areas within the right-of-way that are not sodded or paved should be seeded as follows.

   a. Seeding. Use the seed mixture U as specified in the INDOT *Standard Specifications*. Estimate the quantity assuming an application rate of 165 kg/ha.

   b. Mulching. Use the pay item Mulching Material and estimate it at a rate of 4.5 Mg/ha.

   c. Fertilizer. For estimating purposes, assume an application rate of 900 kg/ha.

3. Rural Areas less than 4000 m^2. For areas within the right-of-way which are not sodded or paved, use the pay item Mulched Seeding, Class R. Estimate the area and pay quantity in square meters.

4. Urban Areas less than 4000 m^2. For areas within the right-of-way which are not sodded or paved, use the pay item Mulched Seeding, Class U. Estimate the area and pay quantity in square meters.

17-3.10(02) Seeding for Grading Projects

The following will apply.

1. Shoulder Point to Shoulder Point. The areas within the outside shoulder points should be seeded as follows.

   a. Seeding. Use the seed mixture P as specified in the INDOT *Standard Specifications*. Estimate the quantity assuming an application rate of 90 kg/ha.

   b. Fertilizer. For estimating purposes, assume an application rate of 450 kg/ha.

2. Shoulder Point to Right-of-Way. The areas within the outside shoulder points and the edge of right-of-way should be seeded according to the requirements for grading and paving projects as discussed in Section 17-3.10(01).

17-3.10(03) Crown-Vetch Seeding

Include crown-vetch seeding, seed mixture CV, on slopes which are 3:1 or steeper, slopes that have granular soils and other slopes which are highly susceptible to erosion. This seed mixture is in addition to the other seed mixtures required for the area (e.g., seed mixture R). For estimating purposes, assume an application rate of 11 kg/ha.

17-3.10(04) Temporary Seeding

Temporary seeding is used to establish seeding on projects where temporary cover is required for soil disturbed during construction operations (e.g., temporary runarounds) and where late season soil stabilization and temporary ground cover is required. The following will apply.

1. <u>Seeding</u>. Use seed mixture T, conventional mix as specified in the INDOT *Standard Specifications*. Estimate the quantity assuming an application rate of 90 kg/ha.

2. <u>Mulching</u>. Use the pay item Mulching Material and estimate it at a rate of 4.5 Mg/ha.

3. <u>Fertilizer</u>. For estimating purposes, assume an application rate of 224 kg/ha.

17-3.10(05) Seeding for Environmental Mitigation

Where environmental mitigation is required by the Environmental Document, the Design Summary, or as determined by a field check, specify one of the following seed mixtures.

1. <u>Seed Mixture Grass</u>. The following will apply to the application of seed mixture grasses.

    a. Type 1. Specify this mixture where a special grass is required in addition to the regular seed mixture. The pay item is Seed Mixture Grass Type 1. For estimating purposes, assume an application rate of 220 kg/ha.

    b. Type 2. This mixture is to be furnished at the contractor’s expense instead of the regular seed mixture in areas that have been disturbed beyond the construction limits in urban areas.

2. Seed Mixture Legume. The following will apply to the application of seed mixture legume.

   a. Type 1. Specify this mixture where a special legume mixture is required in addition to the regular seed mixture. The pay item is Seed Mixture Legume Type 1. For estimating purposes, assume an application rate of 214 kg/ha.

   b. Type 2. This mixture is to be furnished at the contractor's expense instead of the regular seed mixture in areas that have been disturbed beyond the construction limits in rural areas.

   c. Signs. Include "Do Not Spray" signs where this mixture is specified.

17-3.10(06) Wildflower Seed Mixture

Where wildflower seed mixtures are specified, prepare the necessary special provisions so that at least three alternatives of equal cost, type and growing condition are available for the contractor to select. These alternates may be designated by alternate vendors' formulations, by the designer's own non-proprietary formulations or any combination thereof that results in three equal alternatives. Ensure that alternate component varieties for non-proprietary formulations allow the contractor to make substitutions for component varieties that may be in short supply. If the designer has any questions regarding application rates, methods of measurement or pay item descriptions, contact the Design Division's landscape architect.

17-3.10(07) Sodding

In determining the need for sodding, the designer should consider the following.

1. Sod. Sod should be included as described as follows:

   a. in earth ditches that have longitudinal grades of 1.00% to 2.99%;

   b. along paved side ditches (see INDOT *Standard Drawings*);

c. at the bridge cone areas of bridge structures as shown in Figure 17-4 I, Riprap and Sodding Limits with Barrier Transitions on Bridge, and Figure17-4J, Riprap and Sodding Limits with Barrier Transitions on RCBA;

d. in the median ditch for divided lane highways, see Figure 17-3 I, Sodding Locations; and

e. at break points of side slopes, see Figure 17-3 I.

2. Nursery Sod. Nursery sod will be required for all exposed surfaces within the right-of-way in developed areas (i.e., commercial, industrial, residential). Maintained lawns in rural areas disturbed by construction will also require nursery sodding.

3. Estimates. Estimate the area of sod and nursery sod in square meters.

4. Water. To estimate the amount of additional water required for sod and nursery sod, assume a rate of 18 L/m^2. The pay item is measured in kiloliters of water.

17-3.10(08) Mobilization and Demobilization for Seeding

All projects which include seeding pay items should include at least one each of the pay item Mobilization and Demobilization for Seeding. If the project includes a temporary runaround, add at least one additional unit to the estimate. Additional units may be added as required for the likely progression of work (e.g., for the various construction phases).

17-3.11 No-Passing-Zone Pavement Markings

If no-passing zones extend beyond the project limits, striping quantities should include required solid yellow lines and adjacent broken yellow lines to the ends of such no-passing zones.

17-4.0 BRIDGE QUANTITIES

17-4.01 Structural Concrete Quantities

17-4.01(01) Cast-In-Place Concrete

Measure concrete quantities, in cubic meters, based on the theoretical volume for the class and use specified. Do not deduct for the volume of piles, joint material or reinforcing steel within the concrete.

17-4.01(02) Concrete Structural Members

Prestressed I beams and bulb tee beams will be measured and paid for by the meter. There is no measurement and payment per each or lump sum. Prestressed box beams will be measured and paid for by the square meter.

17-4.02 Excavation Quantities

Structure excavation can consist of several types of excavation. In addition to the INDOT *Standard Specifications*, Figure 17-4A, Structure Excavations, and the following discuss the various structure excavation types and how to determine the applicable quantities.

1. Class X Excavation. Specify the pay item Excavation, X, where solid rock, loose stones or boulders more than 0.4 m^3 in volume, concrete footings from old structures not shown on the plans, timber grillages, piles or other similar materials are encountered within the limits of foundation excavation. The volume of class X excavation is determined as follows:

   Class X Excavation = L x W x D

   Where:
   L = length of footing, m
   W = width of footing, m
   D = depth of class X excavation, m (* in Figure 17-4A)

   Note that D extends from the bottom of the footing to the top of the rock elevation.

2. Wet Excavation. Specify the pay item Excavation, Wet, where foundation excavation is encountered below a horizontal plane designated on the plans as the upper limit of wet excavation. The limits for wet excavation quantities are defined as the theoretical volume bounded by the bottom of the footing, the upper limit of wet excavation and vertical planes which are 500 mm outside the neat lines of the footing and parallel thereto. The elevation of the upper limit of wet excavation is the low-water elevation plus 0.3 m. Note that the volume of any class X excavation encountered within these limits must be

subtracted from the wet excavation quantities. The volume of wet excavation is determined as follows:

Wet Excavation = (L + 1 m) x (W + 1 m) x D

Where:	L	=	length of footing, m
	W	=	width of footing, m
	D	=	depth of wet excavation, m (* in Figure 17-4A)

Additional payments may be made outside these limits for the following conditions.

a. The plans show a cofferdam with dimensions that exceed 500 mm outside the footing and the cofferdam is not a pay item. The theoretical volume for wet excavation, in this case, will be based on the dimensions of the cofferdam as shown in the plans.

b. A foundation seal is required. The wet excavation limits will be extended to the bottom elevation of the foundation seal.

If a portion of the present structure lies wholly or partially within the limits of wet excavation, do not alter the pay quantities for wet excavation.

3. Dry Excavation. The volume of dry excavation is the amount of excavation required from the top of wet excavation to the top of proposed ground line (** in Figure 17-4A). Only include the pay item Excavation, Dry, in the project if the quantity exceeds 200 m^3. Where dry excavation is not included as a pay item, these excavation costs are included in the cost of the concrete. The volume of dry excavation is determined as follows:

Dry Excavation = (L + 1 m) x (W + 1 m) x D

Where:	L	=	length of footing, m
	W	=	width of footing, m
	D	=	depth of dry excavation, m (** in Figure 17-4A)

4. Waterway Excavation or Common Excavation. This excavation is the amount of excavation required from the existing ground line to the proposed ground line (* in Figure 17-4A). If this excavation is in the main channel area, it is paid for as Excavation, Waterway. Otherwise it is paid for as Excavation, Common. If it is paid for as common excavation, add this quantity to the previously computed quantity for the road work. If extensive channel work is required, compute the waterway excavation separately.

5. Foundation Excavation (Unclassified). If there are not other types of structure excavation on the project, the excavation required at end bents should be paid for as Excavation, Foundation, Unclassified. Many bridge projects (e.g., reinforced concrete slab bridges with one-row pile interior supports) will use this pay item. The volume of foundation excavation (unclassified) is determined as follows:

   Foundation Excavation (Unclassified) = (L + 1 m) x (W + 1 m) x D

   Where:
   L = length of footing or end bent cap, m
   W = width of footing or end bent cap, m
   D = depth of excavation from the natural ground line to bottom of the foundation, m

17-4.03 Piles

In addition to the criteria in the INDOT *Standard Specifications*, the designer should consider the following information on piles.

1. Exposed/Buried Piles. Piles which consist of an exposed portion and a buried portion should be measured and paid for as two items. For example, the buried portion of a steel encased concrete pile would be paid for as Pile, Concrete, Steel Shell Encased, *(shell thickness)* mm, *(diameter)* mm; and the exposed portion as Pile, Reinforced Concrete, Steel Shell Encased, Epoxy Coated, *(shell thickness)* mm, *(diameter)* mm.

2. Pay Items. When specifying piles, use the pay items as defined in the INDOT *Standard Specifications*. The pay items will include information on the pile diameter/size, the type of encasement, reinforcing steel requirements and the wall thickness of the steel shell.

3. Measurement. The minimum pile tip elevation shown on the General Plan Sheet at stream crossings is established to provide adequate penetration to protect against scour and does not necessarily indicate the penetration needed to obtain the required bearing. The estimated elevation needed to obtain the required bearing is shown only in the Geotechnical Report. The billed length of piling should be computed based on the lower of the minimum tip elevation shown on the General Plan Sheet or the estimated bearing elevation shown in the Geotechnical Report.

4. Incidental Items. Do not include separate pay items for pile encasement, reinforcing steel and concrete filling. These are included in the pay item for the piles.

5. <u>Oversized Predrilled Pile Holes</u>. For integral end bent structures, include a special provision to define the additional payment breakdown required for oversized predrilled holes and uncrushed gravel backfill. Note that the piles themselves should be paid for according to the INDOT *Standard Specifications*. Include this special provision in the plans where the blow count (N) exceeds 115 blows per meter within the 3-m interval below the bottom of the cap.

17-4.04 Steel Sheet Piling

Steel sheet piling required for railroad protection should be shown on the plans. Sheet piling with a higher section modulus than that specified may be required by the railroad company or by the contractor's bearing design. Sheet piling is cut to 0.3 m below the final ground elevation, and left in place after construction is complete. The sheeting is not required for permanent support, but disturbance caused by its removal may be damaging. Steel sheet piling to be left in place is measured by the square meter.

Steel sheet piling required for railroad protection is paid for at the contract unit price per square meter for sheet piling, steel, of the specified section modulus.

17-4.05 Backfill for a Structure

17-4.05(01) Backfill at Bridge Support

1. <u>End Support</u>.

   a. Beam/Girder Type Superstructure. Backfill behind an end bent should consist of coarse aggregate wrapped in a geotextile as shown in the INDOT *Standard Drawings*. An end bent drain pipe should also be included. A structure over water should have the outlet located on the downstream side wherever possible.

   b. Reinforced Concrete Slab Bridge. Flowable backfill should be used to backfill behind an end bent as shown in the INDOT *Standard Drawings*. End bent drain pipes will not be required.

2. <u>Interior Support</u>.

   a. Railroad or Roadway Grade Separation Structure. The area to a point 450 mm outside the neat lines of each footing should be backfilled with structure backfill as shown on the INDOT *Standard Drawings.* The neat line limits and estimated quantities should be shown on the Layout Sheet for each support location.

b. Bridge Over Waterway. The area to a point 450 mm outside the neat lines of each footing should be backfilled with common fill or borrow material.

17-4.05(02) Backfill for Retaining Wall

Chapter Sixty-eight provides the design criteria and warrants for the placement of retaining walls. Figure 17-4B, Cast-in-Place Retaining Wall Quantity Limits, and Figures 17-4C and 17-4D, MSE Retaining Wall Quantity Limits, illustrate the typical pay limits for backfill material quantities for alternative retaining wall designs. Although the contractor may select an alternative wall design, the designer should calculate the backfill material quantities based on the outermost limit of construction for any one wall. These quantities may be assumed for all other retaining wall alternatives.

17-4.06 Roadway Items

Where bridge construction is to be included within road-project limits, the bridge designer should provide the road designer with a Layout Sheet and a General Plan Sheet indicating the proposed roadway construction near the bridge. In addition, the bridge designer will be responsible for providing the road designer with the quantities for the items listed in Figure 17-4E, Bridge Items in Road Plan, so that they can be included with the roadway quantities.

17-4.07 Pavement Markings for Bridge Project

A bridge project should include pay items and quantities for traffic lane stripes, edge lines and signs. A detail or a table illustrating permanent pavement marking limits and quantities should be shown in the plans; see INDOT Typical Plan Sheets. The designer should consider the following.

1. Edge and Center Lines. Determine the quantity for solid, white edge lines and for broken, yellow center lines directly from the plans.

2. No-Passing Zones. The quantity for solid yellow lines to denote no-passing zones is an undistributed item. New solid yellow lines for no-passing zones should be provided for

the entire no-passing zone, even if the no-passing zone extends beyond the limits of the bridge project. Approximate lengths may be determined during the field check. However, actual limits will be determined by the district traffic engineer.

17-4.08 Regulatory and Warning Traffic Signs for Bridge Project

The designer, in conjunction with district personnel during the field check review, should determine whether new traffic signs will be required or if the present ones can be reset.

The method of payment for new regulatory and warning traffic signs is as follows.

1. Posts. Sign posts are paid for by length and type.

2. Signs. Sheet signs are paid for by the area, in square meters, according to the sheeting type and thickness.

Figure 17-4F, Sign Post and Sheet Sign Summaries (Bridge Projects), illustrates the signing tables that should be placed on the Bridge Summary Sheet or on the Approach Detail Sheets. For a project with a small number of signs, the totals may be omitted. For a project with a large number of signs, contact the Design Division's Traffic Sign/Lighting Unit for reproducible Sign Post and Sheet Summary Sheets.

Sign codes, description, size, location, post length and type are listed in the tables according to the guidelines in the *Manual on Uniform Traffic Control Devices*, the INDOT *Standard Drawings* and Chapter Seventy-five. The number and type of posts should be determined according to the procedures in the INDOT *Sign Design Guide*.

17-4.09 Reinforced Concrete Bridge Approach (RCBA)

17-4.09(01) Summary of Bridge Quantities

Quantities for the following items should be included in the Summary of Bridge Quantities table on the Bridge Summary plan sheet.

1. PCCP of the required thickness in the RCBA and extensions, pay unit square meter. See the INDOT *Standard Drawings* for the required RCBA thickness.

2. Epoxy coated reinforcing steel, pay unit kilogram, in the RCBA and extensions.

3. Dense graded subbase, pay unit megagram, placed under the RCBA and extensions.

17-4.09(02) RCBA Details

The designer may not be able to use the details and bill of materials shown in the INDOT *Standard Drawings*. The designer should therefore consider providing complete RCBA details on the bridge plans. Complete details should be provided on the plans where the conditions are present as follows:

1. a bridge that will be constructed in two or more phases;

2. a bridge where the RCBA width must be sufficient to provide for more than two travel lanes, auxiliary lanes, or a median;

3. where variable or nonstandard RCBA lengths, thicknesses, or details are used; and

4. where concrete sidewalks, median barriers, center curbs, lip gutters, etc. must be accommodated.

17-4.09(03) Reinforcing Steel Quantities

Quantities for epoxy coated reinforcing steel in the RCBA and extensions should be shown separately from other reinforcing steel quantities in the Summary of Bridge Quantities table. See the INDOT *Standard Drawings* for details and material quantities for standard RCBA and extensions.

The INDOT *Standard Drawings* provide the dimensions and reinforcement details for a 6200-mm-long RCBA. The INDOT *Standard Drawings* also provide the number, size, and length of reinforcing bars for commonly used RCBA widths. See Figure 17-4G, RCBA Reinforcing Steel Detailing Requirements, for guidance on showing RCBA reinforcing steel details on the plans.

17-4.09(04) Miscellaneous Considerations

The designer should also consider the following.

1. Anchoring. The RCBA should be anchored to the end of the superstructure where integral end bent construction is used. The RCBA should be anchored to the adjacent mudwall where a bridge deck expansion joint is used at the end of the superstructure. See Chapter Sixty-seven for connection details.

2. Polyethylene Fabric. Two layers of polyethylene fabric, each of 0.150 mm minimum thickness, should be placed between the concrete bridge approach slab and the subgrade where the RCBA is anchored to the superstructure.

3. Terminal Joint. A terminal joint or pavement relief joint of 600 mm width should be provided at the roadway end of the RCBA if any portion of the adjacent pavement section is PCC. No such joint is required if the entire adjacent pavement section is HMA.

4. Dimensions. The RCBA length of normally 6200 mm, and the width and thickness should be shown on the plans.

   The length and width are typically shown on the General Plan Sheet. The RCBA thickness may be shown on a superstructure or end-bent detail sheet.

17-4.10 Riprap and Sodding Limits at Bridge Cone

Figure 17-4 I, Riprap and Sodding Limits with Barrier Transitions on Bridge, and Figure17-4J, Riprap and Sodding Limits with Barrier Transitions on RCBA, illustrate the placement of riprap and sodding at a bridge cone to control erosion. Figure 17-4 I illustrates the placement where the barrier transitions are on the bridge and Figure 17-4J where they are on the RCBA. Riprapping the surfaces of the bridge cones and fill slopes adjacent to the RCBA (Figure 17-4J) is recommended for a new bridge at a stream crossing. Where mowing equipment experiences difficulty traversing riprap drainage turnouts for a grade separation structure (e.g., at an interchange), the bridge cone surfaces may be sodded instead.

On a bridge rehabilitation project, the designer should review proposed erosion control techniques (e.g., erosion control mat, riprap drainage turnout, sodded flume, curb inlet/piping) with the Design Division’s Bridge Rehabilitation Unit and the district.

17-5.0 MATHEMATICAL FORMULAS

Mathematical formulas shown in Figure 17-5A, Formulas for Geometric Shapes, are used by INDOT for various quantity determinations.